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doi:10.1017/S1431927611007574

Microsc. Microanal. 17 (Suppl 2), 2011

HRTEM Study of Dissociated Dislocation Structures in Low-Angle Grain Boundaries of Alumina

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Alumina (α-Al_2O_3) is widely used for high-temperature structural applications. Since plastic deformation occurs by dislocation glides, it is important to understand the structures of dislocations with an atomic level. In alumina two major slip systems, $(0001)1/3\langle 11\bar{2}0\rangle$ and $\{11\bar{2}0\}\langle 1\bar{1}00\rangle$, are dominantly activated at elevated temperatures [1]. These slip dislocations are observed to be dissociated into $1/3\langle 10\bar{1}0\rangle$ partial dislocations as following equations.

$$1/3\langle 11\bar{2}0\rangle \rightarrow 1/3\langle 10\bar{1}0\rangle + 1/3\langle 01\bar{1}0\rangle \qquad (1)$$
$$\langle 1\bar{1}00\rangle \rightarrow 1/3\langle 1\bar{1}00\rangle + 1/3\langle 1\bar{1}00\rangle + 1/3\langle 1\bar{1}00\rangle \qquad (2)$$

Alumina possesses the so-called corundum structure, and the $1/3\langle 1\bar{1}00\rangle$ fault vector coincides with a translation vector in the anion sublattice but not in the cation sublattice. Thus, $1/3\langle 1\bar{1}00\rangle$ partial dislocation leads stacking faults in the cation sublattice. The stacking faults are formed on the $\{11\bar{2}0\}$ or $\{1\bar{1}00\}$ planes [2]; however their atomic structures and fault energies are not experimentally well characterized yet.

Low-angle grain boundaries consist of edge dislocations. Burgers vectors of the dislocation are usually selected to be normal to the grain boundary planes. In order to characterize the structures of $1/3\langle 11\bar{2}0\rangle$ and $\langle 1\bar{1}00\rangle$ dislocations, we fabricated alumina bicrystals with the $\{11\bar{2}0\}/\langle 1\bar{1}00\rangle$ 2^o and the $\{1\bar{1}00\}/\langle 11\bar{2}0\rangle$ 2^o low-angle tilt grain boundaries and observed the boundary dislocations by high-resolution transmission electron microscopy (HRTEM).

FIG. 1 shows a HRTEM image of dislocation pairs formed in the $\{11\bar{2}0\}/\langle 1\bar{1}00\rangle$ grain boundary. An analysis using Burgers circuit revealed that they are $1/3\langle 10\bar{1}0\rangle$ and $1/3\langle 01\bar{1}0\rangle$ partial dislocations formed by the dissociation reaction of EQ. 1, and it is found that the stacking fault is formed $\{11\bar{2}0\}$ plane. The average interval of partial-dislocation pairs and width of the stacking faults were 14.7 nm and 3.3 nm, therefore the stacking fault energy are estimated to be 0.32 Jm^{-2} by elastic theory (where the infinite dislocation configuration was considered [3, 4]). FIG. 2 shows a HRTEM image of dislocation triplets formed in the $\{1\bar{1}00\}/\langle 11\bar{2}0\rangle$ low-angle grain boundary. From Burgers circuits the total fault vector of the triplet is found to be $\langle 1\bar{1}00\rangle$ and each partial dislocation has the $1/3\langle 1\bar{1}00\rangle$ vector. This is consistent with the dissociation reaction based on EQ. 2. The partial dislocations are connected with two stacking faults on the $\{1\bar{1}00\}$ plane. The average interval of partial-dislocation triplets and width of the stacking faults were 22.4 nm and 5.3 nm, and the stacking fault energies are estimated to be 0.40 Jm^{-2}. It is noted that the right and the left stacking faults are different in structure [2, 5]. In the presentation, we will discuss the dissociated dislocation structure in detail, and we will also demonstrate dopant segregation behavior around the dislocation cores by HAADF-STEM.

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[6] This work was supported in part by the Grant-in-Aid for Scientific Research on Priority Areas "Nano Materials Science for Atomic-scale Modification" (no. 19053001) from the Ministry of Education, Culture, Sports and Technology (MEXT). E.T. was supported as a Japan Society for the Promotion of Science (JSPS) research fellow.

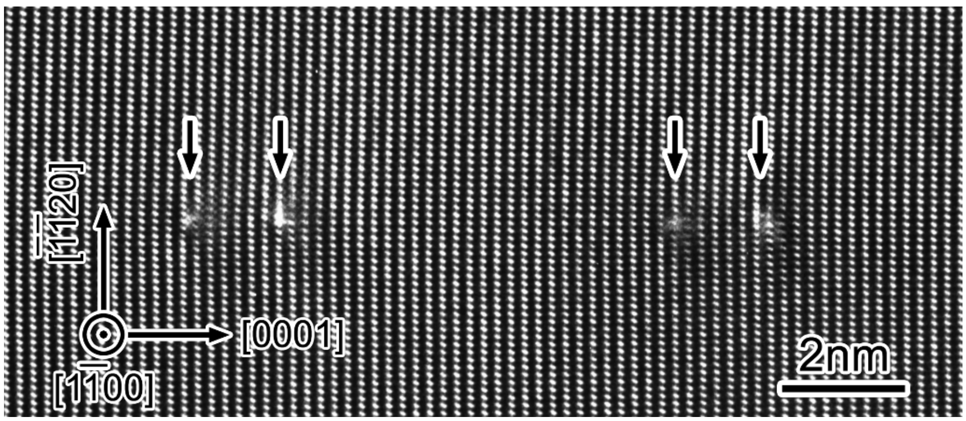

FIG. 1. A HRTEM image of {11$\bar{2}$0}/<1$\bar{1}$00> 2° tilt grain boundary. The dislocations dissociate into 1/3<10$\bar{1}$0> and 1/3<01$\bar{1}$0> partial dislocations with a stacking fault on the {11$\bar{2}$0} plane.

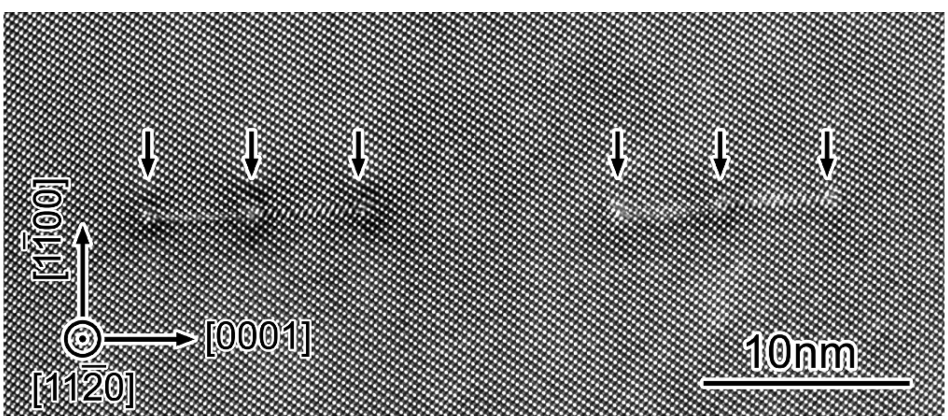

FIG. 2. A HRTEM image of {1$\bar{1}$00}/<11$\bar{2}$0> 2° tilt grain boundary. The dislocations dissociate into three 1/3<1$\bar{1}$00> partial dislocations with stacking faults on the {1$\bar{1}$00} plane.

https://doi.org/10.1017/S1431927611007574 Published online by Cambridge University Press